Processes leading up to the 22 ka silicic caldera-forming eruption of Santorini (Greece): Constraints from crystal trace-element fingerprinting and diffusion chronometry

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How does the plumbing system of a volcano evolve in the build-up to a large, silicic eruption?

Traditional view

Slow, gradual accumulation of magma into a single magma reservoir over 1,000s–10,000s of years

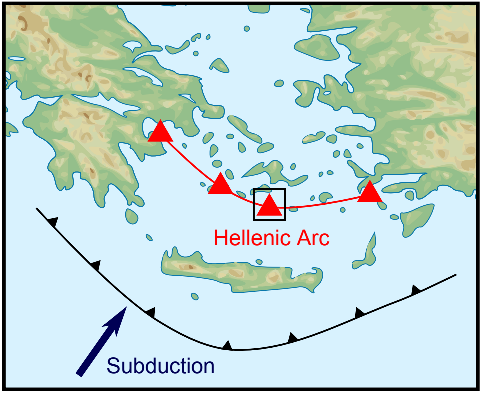
Sometimes accompanied by effusive "precursory leaks" from this growing reservoir

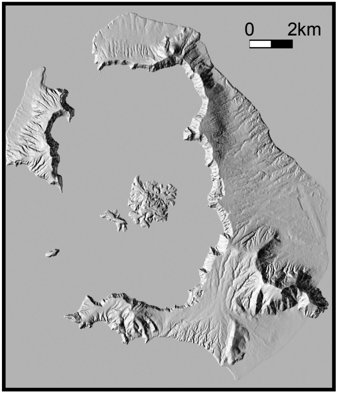
Approach

Two different timescale constraints on a single system:

1. Fieldwork, $^{39}Ar/^{40}Ar$ dating and whole rock chemistry of the "precursory leaks"
2. Trace element fingerprinting and diffusion chronometry of the crystals

Location of Santorini — Hellenic Arc





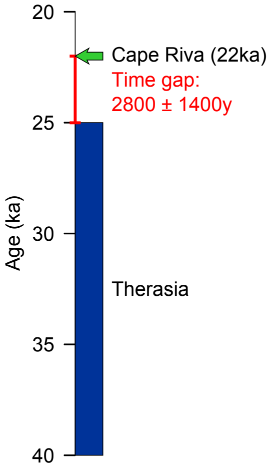
Youngest Therasia lava erupted 2800 ± 1400 before the Cape Riva

Cape Riva

$\gtrsim$10 km^3
64–67 wt% SiO_2

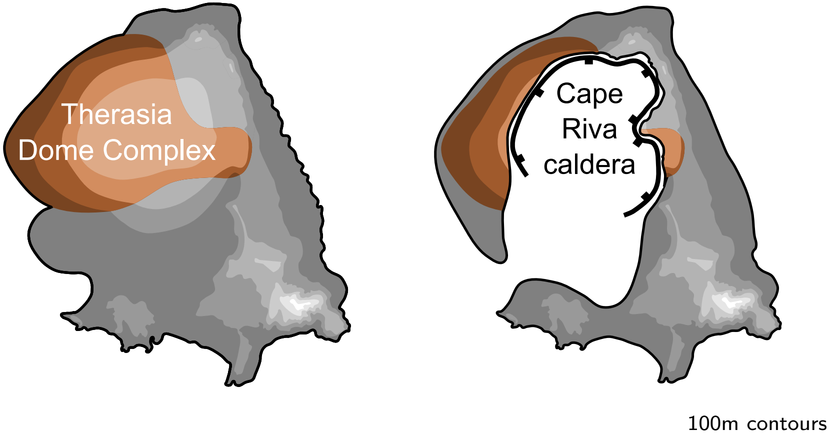
Therasia Dome Complex

$\sim$1-2 km^3
65–69 wt% SiO_2



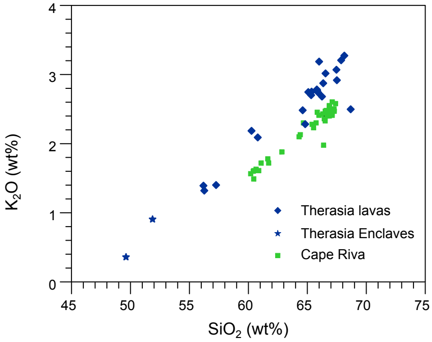
See poster (today, 13:30–15:00) for more info

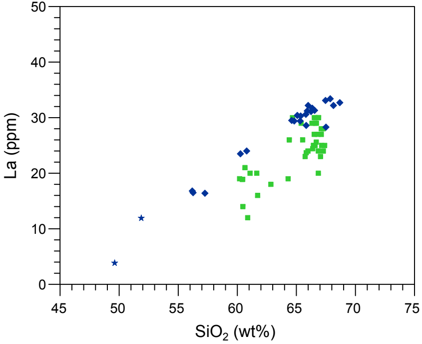
Cape Riva and Therasia magma bodies located in same volume under the north of the island



Depth of magma chamber: 2 ± 0.5 kbar (Cadoux *et al*, submitted)

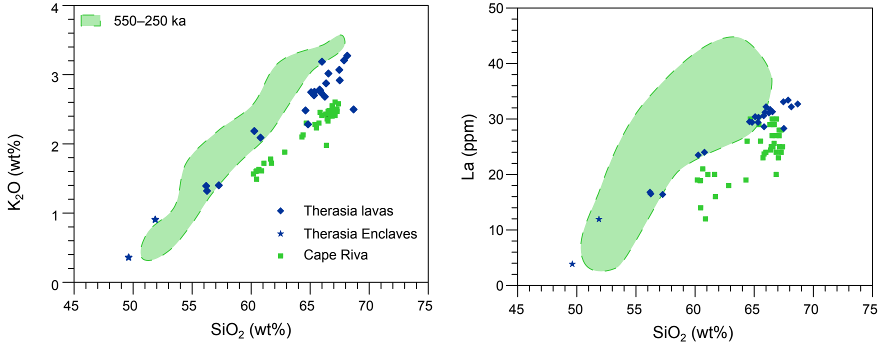
The Cape Riva is depleted in incompatibles





Also Rb, Nd, Zr, Ce, LREE, HREE

The Cape Riva is a new silicic magma batch



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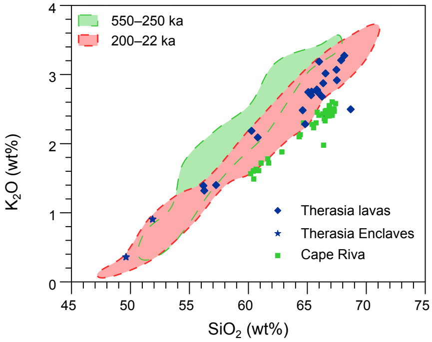

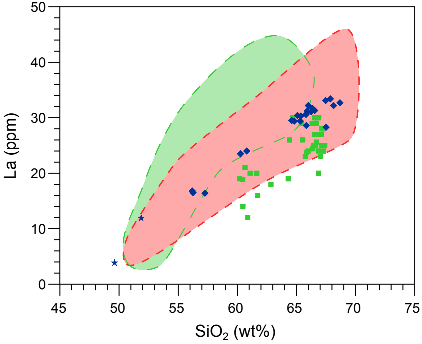

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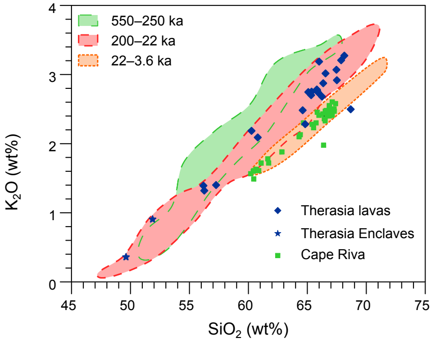

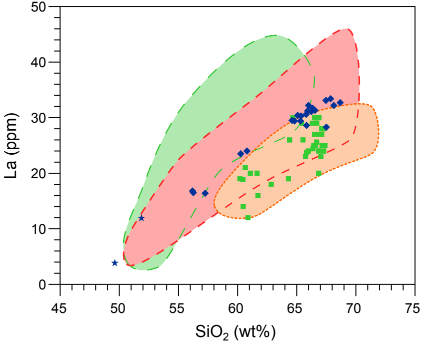

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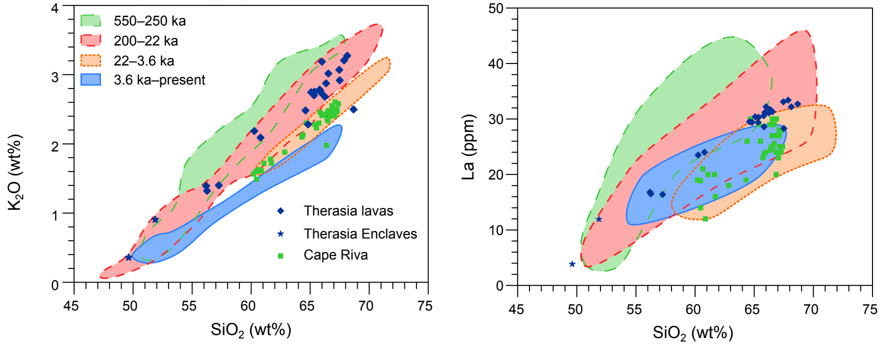

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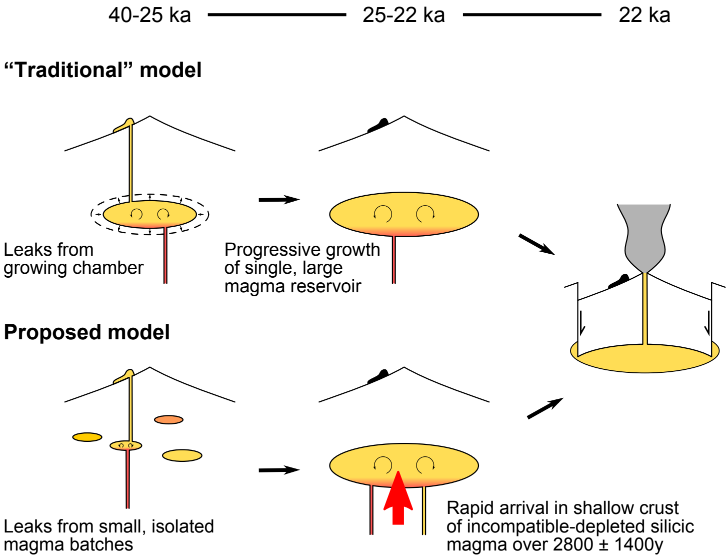
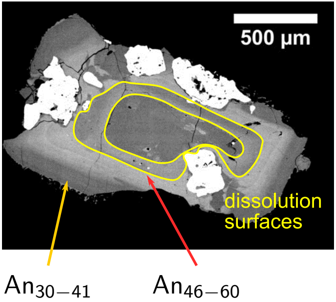
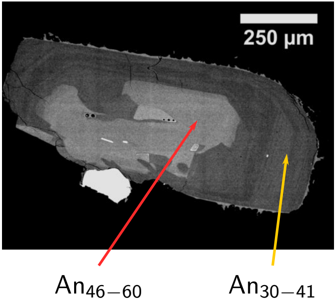
The Cape Riva magma chamber assembled over 2800 ± 1400 years

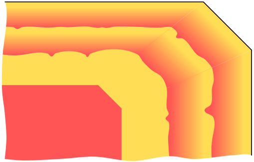


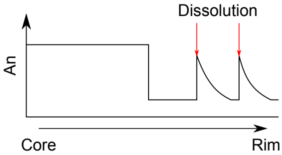
Cape Riva Petrology

15–20 wt% crystals: Plagioclase >> orthopyroxene > clinopyroxene > oxides

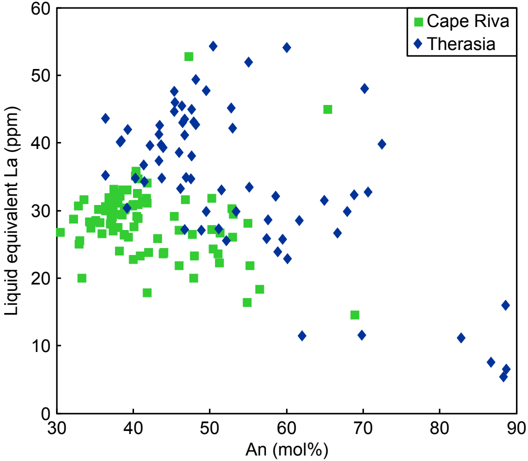








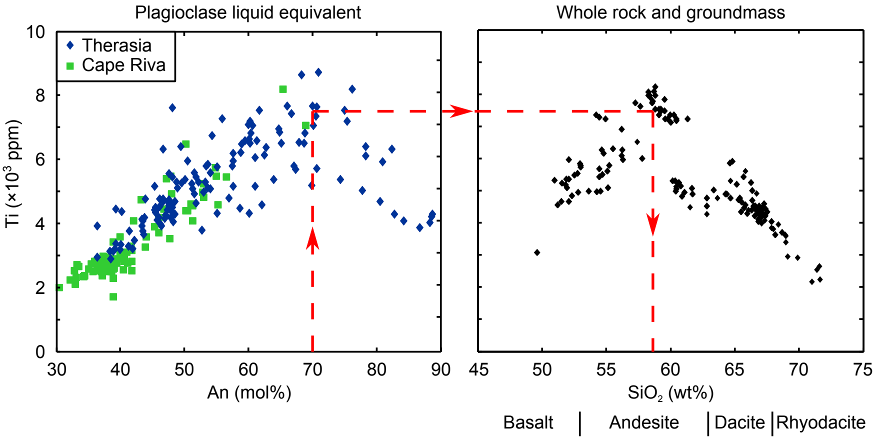
Cape Riva and Therasia plagioclase have different sources



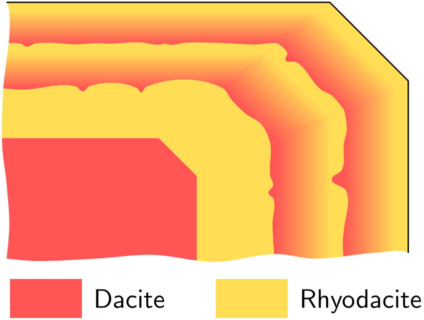
Equivalent liquids from partition coefficients and temperature given by:

$$An_{40} : 850\,^{\circ}C \rightarrow An_{80} : 1050\,^{\circ}C \qquad T = 850 + X_{An}\frac{1050-850}{80-40}$$

Ti can be used to match up anorthite content with corresponding whole rock data

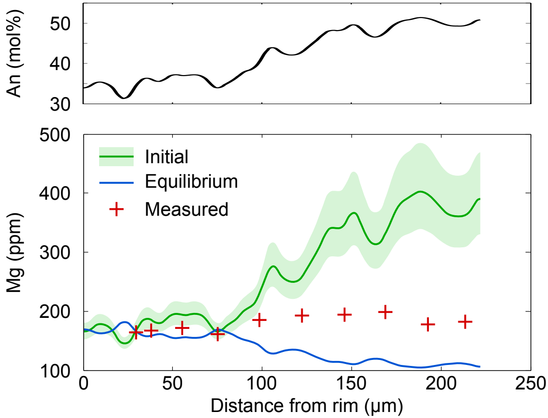


Plagioclase record mixing between dacite and rhyodacite



- Mixing magmas of different compositions to produce different plagioclase compositions
- Cooling and/or decompression to grow the crystals

Modelling Mg diffusion in plagioclase



- An from BSE images calibrated using EMP
- Initial Mg from whole rock (via Ti)
- Actual Mg by LA ICP-MS

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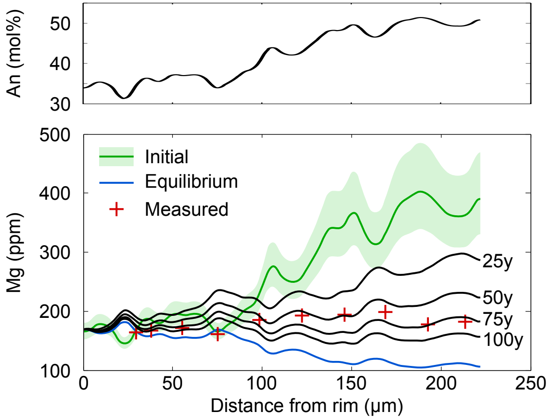
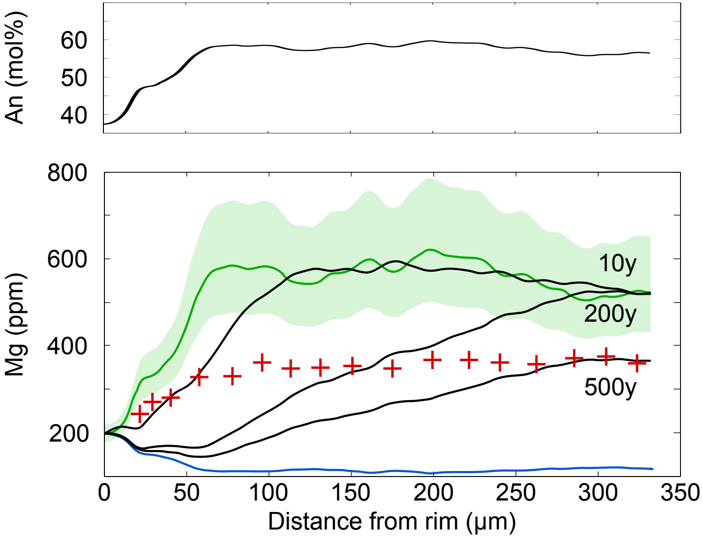


- An from BSE images calibrated using EMP
- Initial Mg from whole rock (via Ti)
- Actual Mg by LA ICP-MS
- Mg diffusion coefficient from van Orman *et al.* (LPSC 2012)
- Temperature from Fe-Ti oxides (880°C)

2 stage diffusion models



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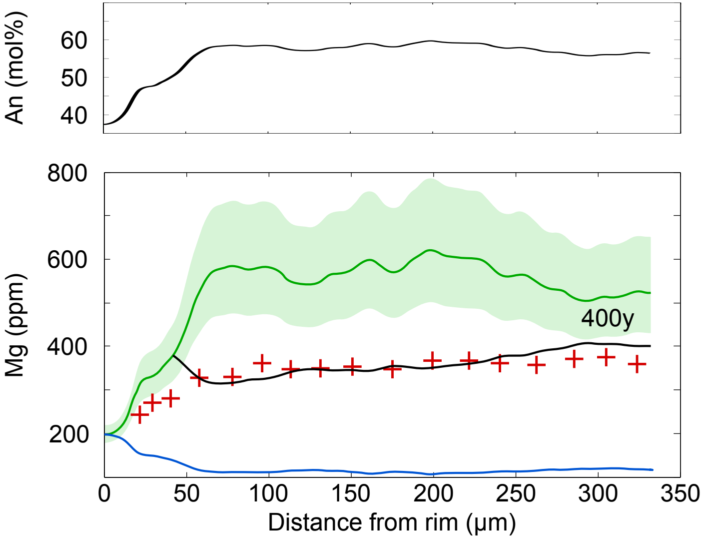

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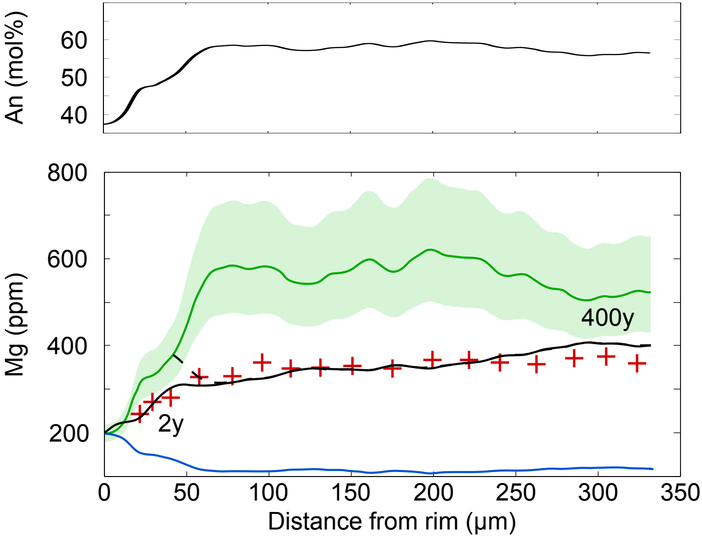
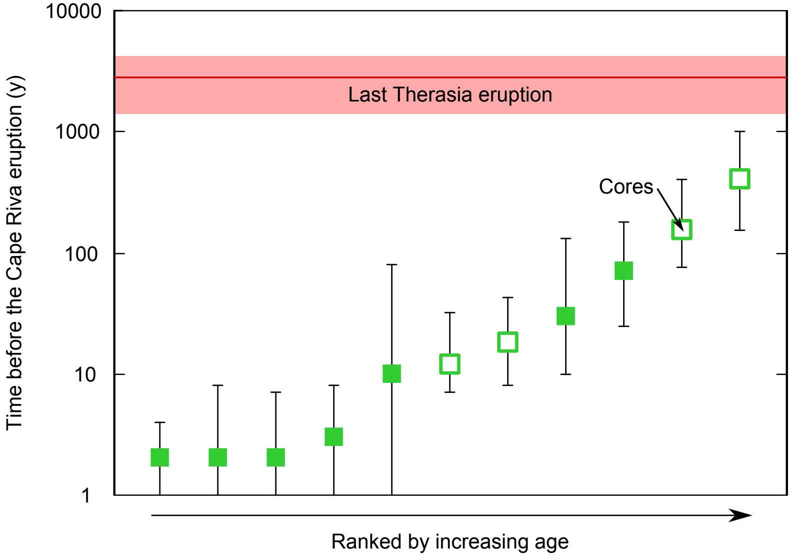


Plagioclase grew years to decades before eruption



Conclusions

- The Therasia dacites were extruded over 15 ky prior to the Cape Riva eruption
- The Therasia and Cape Riva dacites are very similar in terms of petrology and major element concentrations, and were erupted from a magma reservoir with a similar location
- **However:** the incompatible element concentrations in both whole rock and plagioclase show that the Cape Riva dacite is a new silicic magma batch
- Two timescale constraints on the arrival of the Cape Riva magma batch:
  - $^{39}Ar/^{40}Ar$ data constrain the arrival into the shallow system to $\lesssim$2800 years before eruption
  - The vast majority of the Cape Riva plagioclase crystallised years to decades before eruption; this crystallisation event may record the ascent of the Cape Riva magma